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On Al-Sūfi's Star Magnitudes. By E. B. Knobel.

In vol. xiv. of the "Annals of Harvard College Observatory," Prof. Pickering has drawn attention to some alleged differences between the magnitudes of Ptolemy's stars as given by Al-Sūfi in his "Description of the Constellations," and by Ulugh Beigh in his Catalogue. These discrepancies are given on the authority of Dr. C. H. F. Peters, who has published in the *Astronomische Nachrichten*, xcix. 235, a list of 74 differences which he finds in comparing Schjellerup's translation of Al-Sūfi with Hyde's translation of Ulugh Beigh.

As Prof. Pickering has given a table entitled "Differences between Sūfi * and Ulugh Beg," we might be led to infer that Ulugh Beigh had really made some estimations of star magnitudes, and in that case the question would deserve investigation.

The only information we possess as to the construction of Ulugh Beigh's Catalogue of Stars is contained in his Preface to the Catalogue, which has been translated into Latin by Hyde, and into French by Sédillot, and forms chapter xiii. of the Third Part of his "Prolégomènes des Tables Astronomiques d'Oloug-Beg." The chapter is short, and as Sédillot's work is rather scarce, I beg to transcribe it.

"Avant Ptolémée on avait observé 1022 étoiles fixes; Ptolémée les a placées dans un catalogue inséré dans *l'Almageste*.

"On a distribué ces étoiles en six grandeurs; les plus grandes sont de la première grandeur, et les plus petites de la sixième grandeur.

"On a aussi établi trois ordres dans chaque grandeur, et pour reconnaître les étoiles on a imaginé 48 Figures ou Constellations, dont 21 sont au nord de l'écliptique, 12 dans le zodiaque, et 15 au midi.

"La plupart des étoiles sont dans les figures mêmes; les autres sont aux environs, et on les désigne par le nom d'externes de la constellation.

"Abderrahman Soufi a composé un Traité des étoiles que tous les savants ont reçu avec empressement.

"Avant de determiner par nos propres observations le lieu de ces étoiles nous les avons fait disposer sur des sphères d'après ce Traité et nous les avons trouvées pour la plupart placées différemment qu'on ne le juge à l'inspection du ciel.

"Cela nous a déterminé à les observer nous-mêmes avec le secours de la protection Divine et nous avons réconnu qu'elles étaient avancées en raison de l'époque à laquelle l'ouvrage a été composé, de sorte qu'en leur donnant selon cette observation

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* This author is erroneously called "Sūfi" in modern works. His correct name appears to be Abd-al-Rahman Al-Sūfi (pronounced Abdurrahman Assūfi). That is to say, Abd-al-Rahman *the* Sūfi, because he belonged to the old and existing religious sect of the Sūfies. It seems, therefore, incorrect to call him simply Sūfi.

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générale, la position absolue qui leur convient, nous n'avons plus trouvé la différence qu'elles présentent à l'œil.

" C'est d'après ce principe que nous avons réobservé toutes les étoiles déjà déterminées à l'exception toutefois de vingt-sept qui ne sont pas visibles à la latitude de Samarcande à cause de son grande éloignement du midi : savoir, les sept de la figure de l'Encensoir (*Ara*), huit dans le Navire de la 36$^{\text{me}}$ à la 41$^{\text{me}}$ et les 44$^{\text{me}}$ et 45$^{\text{me}}$; onze dans le Centaure depuis la 27$^{\text{me}}$ jusqu'à la dernière, et une, la 10$^{\text{me}}$, dans la constellation du Loup ; et nous avons pris ces vingt-sept étoiles dans le livre d'Abderrahman Soufi en tenant compte de la différence de l'époque (de son catalogue et du nôtre).

" En outre il y a huit étoiles dont Abderrahman Soufi fait mention dans son livre comme ayant été placées en leur lieu respectif par Ptolémée, mais que lui Abderrahman n'y a pas vues et que malgré toutes nos récherches nous n'avons pu nous-mêmes découvrir ; c'est pourquoi nous n'indiquons pas ces étoiles dans le présent catalogue : ces étoiles de Ptolémée sont la 14$^{\text{me}}$ du Cocher (*Auriga*), la 11$^{\text{me}}$ du Loup et les six externes du Poïsson Austral.

" Nous établissons dans notre catalogue le lieu des étoiles pour le commencement de l'année 841 de l'Hégire afin qu'en tel temps qu'on voudra on puisse retrouver le lieu de chacune dans la supposition qu'elles avancent d'un degré en 70 années solaires."

As Ulugh Beigh based his catalogue upon that of Al-Sūfi, and makes no mention of any observations of the brightness of the stars, it is not unreasonable to infer that the magnitudes he gives are simply copied from Al-Sūfi, and in that case the alleged " differences between Sūfi and Ulugh Beg " can be nothing more than differences in the MSS., due to transcribers and translators.

It may be mentioned at once that two of the alleged differences are in the case of the 29th and 31st stars in *Centaurus*, which Ulugh Beigh particularly states are not visible at the latitude of Samarcand, and which he therefore copied from Al-Sūfi.

In the *Monthly Notices* for 1879 (vol. xxxix.) I have given a complete translation of the star magnitudes in the Persian MS. of Ulugh Beigh belonging to the Society, and I have shown that this MS., compared with the two editions of Hyde's translation from Oxford MSS., contains 158 different readings. Forty-eight of the supposed differences with Al-Sūfi are here found to have no existence.

Great interest attaches to the description of the constellations and the undoubtedly original estimations of star magnitudes by Al-Sūfi, which makes it worth while investigating all available MSS.

With this object I have examined two Arabic MSS. of Al-Sūfi's " Description of the Constellations," one at the British Musem (Additional MSS. 7488), and the other in the India Office Library (Arabic MS. 2389), which, through the kindness of the Secretary of State, has been lent to me.

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Unfortunately, neither of these MSS. is complete. That at the British Museum is of the fifteenth or sixteenth century—well and clearly written, and the drawings of the constellations beautifully executed. The catalogue of the stars in *Equuleus*, *Canis Major*, and the *Informatæ* of *Piscis Australis*, are omitted.

The India Office MS. is probably of a later date. It can be considered only as a fragment, inasmuch as it does not contain the catalogues of *Ophiuchus*, *Serpens*, *Sagitta*, and *Canis Major*, nor the descriptions of *Serpens*, *Sagitta*, and *Aquila*; and the MS. terminates with the description of *Argo*; wanting therefore the catalogue of *Argo*, and the descriptions and catalogues of *Hydra*, *Crater*, *Corvus*, *Centaurus*, *Lupus*, *Ara*, *Corona Australis*, and *Piscis Australis*.

The value of a MS. of Ptolemy or Al-Sūfi depends largely upon the care and accuracy with which the subdivisions of the star magnitudes are indicated. In the Greek *Almagest* these are expressed by the words *μείζων* and *ἐλάσσων* appended to the magnitude. In the Latin *Almagest*, translated from the Greek by Trapezuntius, by "ma" (major) and "mi" (minor). In the Liechtenstein Latin *Almagest*, translated from the Arabic by Gerard of Cremona, by "em" (presumably for *μείζων*) and "el" (*ἐλάσσων*). In the British Museum Arabic *Almagest* of A.D. 1218, by the Arabic letters mīm م and lām ل. (These two last examples suggest that the original Arabian scribe, who translated from the Greek, had no idea of the meaning or the application of the words *μείζων* and *ἐλασσων*, and therefore appended the initials of the Greek words in Arabic letters). In the Bodleian Library Arabic *Almagest* and the several MSS. of Al-Sūfi and Ulugh Beigh, these subdivisions are expressed by the letters Kāf and Sād, being the initials of the words كبير (large) and صغير (small). Thus *γ μείζων*, 3 ma, 3 em, جم, جك, all express that the magnitude is 3–2.

In the oriental MSS. I have examined, great care has always been taken by the scribes in ruling the necessary columns for entering the catalogues of stars; but in all cases, the last column is ruled only wide enough to insert the number expressing the magnitude, rendering it necessary for the qualifying letters, which indicate that the magnitude is either a large or a small one, to be written in the margin. And as the majority of the magnitudes are without such letters, there is nothing to indicate to the scribe that they are omitted, and so hardly any MS. appears to give the whole series complete.

In the British Museum MS. of Al-Sūfi very many of the initial letters referred to are omitted. From the constellation *Argo* (where there are indications of a change in the writing) to the end of the MS. they are entirely omitted.

In the India Office MS. they are omitted altogether from beginning to end.

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Notwithstanding these imperfections, I think it may be interesting to compare the differences between these MSS. and those translated by Schjellerup. I therefore submit a table showing the different readings I have found; and I think that there are enough variations in the MSS. to indicate that we cannot feel sure that we yet possess a sufficiently perfect edition of Al-Sūfi's star magnitudes to warrant the assumption that any differences between him and the Ulugh Beigh MSS. may be due to original observations by the Samarcand astronomer.

In the following table the first column gives Ptolemy's number of the star in the constellation. In the second column the magnitudes in the British Museum and India Office MSS. of Al-Sūfi, indicating the latter by the letters I.O. This MS. being devoid of letters qualifying the magnitudes, I give only those cases which are entirely discordant with the other texts. The third column gives the magnitudes in Schjellerup's *Tableau Synoptique.*

Al-Sūfi's Star Magnitudes.

Differences in the following Arabic MSS.:—
British Museum. Add. MSS. 7488 = Brit. Mus.
India Office MS. 2389 = I.O.
St. Petersburg MS. } examined by Schjellerup = Schj.
Copenhagen MS. }

Constellation	No.	Brit. Mus.	Schj.
Ursa Minor	5	5	5–4
Draco	5	3 3 I.O.	2–3
	10	3 3 I.O.	4
	11	4–5 4 I.O.	3–4
	16	5	5–4
	19	4	4–3
	27	3	3–4
	28	5	5–4
	29	3	3–4
	30	3	3–4
	31	3	3–4
Cepheus	1	4	5–4
	3	4	4–3 3–4
	8	4 5 I.O.	4–3
	11	4 6 I.O.	6
Boötes	1	5	5–4
	2	5	5–4
	3	5	5–4
	18	4	4–3
Corona	3	4	4–5
Hercules	13	5	5–6 6–5
	14	5	5–6 6–5
	15	4	4–3
	25	4	4–3
Lyra	2	4	4–3
	3	4	4–3
	4	4	4–3
	5	4	4–5
	6	4	4–5
	7	3	3–4
	8	4	4–5
	10	5	5–6
Cygnus	1	3	3–4
	2	6	6–5

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Constellation.	No.	Brit. Mus.	Schj.
Cygnus	4	3	3–2*
	7	4	4–5
	10	4 3 I.O.	3
	11	4	4–5
	12	4 3 I.O.	3
	15	4	4–3
Informatæ	1	4	4–3
Cassiopea	1	4	4–3
	4	3	3–2
	7	4	4–5
	8	4	4–5
	11	4	4–5
Perseus†	3	3	3–4
	4	4	4–5
	12	2	2–3
	13	4	4–5
	14	4	4–3
	25	3	3–4
	26	3	3–4
Informatæ	1	5	5–6
	2	5	5–6
Auriga	10	3	3–4
Ophiuchus	2	3	3–4
	5	4	4–3 3–4
	8	3	3–4
	9	5	5–4
	10	4	4–3
	13	4	4–5 5–4
	14	4	4–5 5–4
	15	4	4–3
	16	4	4–5
	18	5	5–6

Constellation.	No.	Brit. Mus.	Schj.
Serpens	2	4	4–5
	3	3	3–4
	4	3	3–4 3
	6	4	4–5
	7	3	3–4
	8	3	4
	10	3	3–4
	14	4	4–3
	17	4	4–3
Aquila	2	3	3–4
	3	2	2–1
	9	5 3 I.O.	3
Informatæ	1	3	3–4
	3	3	3–4
	4	4	4–5
	6	3	3–4
Delphinus	1	4	4–3
	4	3	3–4
	5	3	3–4
	6	3	3–4
	7	3	3–4
Pegasus	1	2	2–3
	2	2	2–3
	3	2	2–3
	4	2	2–3
	13	5–6 5 I.O.	5–6 6
	14	5–6 5 I.O.	5–6 6

Enumeration in I. O. MS. gives four stars of mag. 3 and four of mag. 5. Schj. gives three of mag. 3 and five of mag. 5.

Andromeda	9	4–5	4–3
	14	4	4–5

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* Mag. 3 in Catalogue.

† In Schjellerup's enumeration of the stars there is an error: for "une de la sixième" read "une nébuleuse."

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Constellation.	No.	Brit. Mus.	Schj.
Andromeda	17	4	4–3
	18	4	4–3
	21	5–6 5 I.O.	5–6 6–5
	22	5–6 5 I.O.	5–6 6–5
Triangulum	3	5	5–6
	4	3	3–4
Aries	12	5 4 I.O.	5

Enumeration, I. O. MS. gives five of mag. 4 and five of mag. 5. Schj. gives four of mag. 4 and six of mag. 5.

Constellation.	No.	Brit. Mus.	Schj.
Informatæ	1	3–4	3–2
Taurus	8	4 5 I.O.	4–3
	10	4–3	4
	23	4	5
Informatæ	6	6	6–7
Gemini	7	4–5	4–3
	9	5	5–4
	10	3	3–4
	15	3–2 4 I.O.	4–3
	16	3	3–4
	17	3–2	3
	18	4–5	4

Enumeration, I. O. MS. gives five of mag. 3 and nine of mag. 4. Schj. gives six of mag. 3 and eight of mag. 4.

Constellation.	No.	Brit. Mus.	Schj.
Gemini Informatæ	1	4–5	4–5 5–4
	4	6 I.O.	5–6
	5	6 I.O.	5–6
	6	6 I.O.	5–6

Enumeration, I. O. MS. gives one of mag. 5 and three of mag. 6. Schj. gives four of mag. 5 and none of mag. 6.

Constellation.	No.	Brit. Mus.	Schj.
Cancer	3	4–5	4–5 5–4
	8	4 5 I.O.	5–6 6–5
	9	4–5	4
Informatæ	1	4	4–5
	2	5	4–5
Leo	3	3	3–4
	4	3	3–2
	13	4	4–3
	19	5	5–4
	23	3	3–4
	24	4	4–3
Informatæ	3	4	4–5
Virgo	11	5	5–6
	14	1	1–2
	15	3	3–4
	16	5	5–6 6–5
	18	5	5–6
	19	5	5–6 6–5
	20	5	5–6
	25	4–5	4
	26	4	4–3
Informatæ	5	6 5 I.O.	5
Libra	2	5–6	5–6 6–5
	4	5–6	5–6 6–5
	5	4–5	4
	6	5	5–6 6–5
Scorpio	4	3–4	3–4 4–3
	7	3	3–4
	16	3	3–4 4–3

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Constellation.	No.	Brit. Mus.	Schj.
Scorpio	18	3	3–4
	21	3	3–4
Informatæ	1	4	4–5
Sagittarius	7	4	4–3
	11	4	4–3*
	16	5	5–6
	18	5	5–6
	19	4	4–5
	20	5	5–6
	21	4	4–3
	23	4	4–5
	24	4	4–5
	25	3	3–4
	26	4	4–5
	27	4	4–5

Enumeration, I. O. MS. gives seven of mag. 3 and thirteen of mag. 4. Schj. gives six of mag. 3 and fourteen of mag. 4, not accordant with the magnitudes in the Catalogue.

Constellation.	No.	Brit. Mus.	Schj.
Capricornus	2	6 I.O.	5–6
	4	6	—†
	11	6 I.O.	4
	14	4	4–5
	15	5	5–4
	16	4	6
	17	4	6
	18	4	5–6
	20	3	4
	21	3	4
	22	3	4–5
	23	3	3–4
	25	4	5–6

Enumeration, I. O. MS. gives seven of mag. 3, four of mag. 5. Schj. gives four of mag. 3 and seven of mag. 5.

Constellation.	No.	Brit. Mus.	Schj.
Aquarius	1	6	6–7
	2	3	3–4
	4	3	3–4
	7	5	5–6
	8	4	4–3
	9	3	3–4
	10	4	4–3
	11	3	3–4
	12	3	3–4
	14	5	5–6
	15	4	4–5
	16	4	4–5 5–4
	17	4	6
	21	5–6 6 I.O.	5–6
	29	5–6	4
	30	5	5–6
Pisces	1	4–5	4
	16	4	4–5
	17	4–5	4
	19	3–4	3–4 4–3
	22	3	3–4 4–3
	25	5	5 4
	26	6	6–7‡
	27	6	6–7‡
	28	6	6–7‡
	31	4	—§
Cetus	16	3	3–4
	19	5	5–6 6–5
	20	5–6	5–6 6–5
Orion	12	5	5–6
	16	5–6	5
	24	3	3–4
	29	3	3–4
	31	3	3–4

* Mag. 4 in Catalogue.

‡ Mag. 6 in Catalogue.

† Mag. 6·7 in Catalogue.

§ Mag. 4 in Catalogue.

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Constellation.	No.	Brit. Mus.	Schj.
Orion	35	1–2	1
	36	4	4–3
	38	3–2	3–4*
Eridanus	1	4 6 I.O.	4
	3	4–5	4–5 5–4
	12	3–4	3–4 4–3
	17	5–6	5–6 6
	19	4	4–5
	20	4	4–3
	24	5	5–6
	27	4	4–5
	30	4	4–3
	34	4† 1 I.O.	1
Lepus	9	4–5	4–3
	10	4–5	4–3
Argo	3	4	4–3
	5	5	5–6
	6	4	4–3
	10	4	4–5 5–4
	11	5	5–6
	25	4	4–3
	26	4	4–3
	27	3	4
	28	3	4
	29	4	4–5 5–4
	30	4	4–5 5–4
	33	4	4–3
	36	3	4
	41	4	4–3
Argo	42	5	4
	43	3	3–4
	45	3	3–4
Hydra	1	4	4–5
	4	5	4
	5	4	4–3
	8	4	4–5 5–4
	9	4	4–5
	10	4	4–5
	11	6	6–7
	13	5	4
	15	4	4–3
	16	3	3–4
	17	4	4–5
	18	4	3
	21	3	4–3
	22	3	4
	24	3	3–4
	25	4	3–4
Crater	4	5	5–6
	5	4	4–5 5–4
	6	4	4–5
	7	4	4–5
Corvus	1	3	3–4
Centaurus	8	4	4–5
	12	4	4–3
	13	4	4–3
	15	4	4–3
	17	4	4–3
	21	4	5
	25	5	5–4
	28	5	5–6 6–5
	30	omitted	omitted
	33	3	3–4

* Mag. 3 in Catalogue.

† An obvious error. I am not aware of any other instance of *Ultima Fluvii* not being mag. 1.

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Constellation.	No.	Brit. Mus.	Schj.	Constellation.	No.	Brit. Mus.	Schj.
Centaurus	36	2	2–1	Ara	3	4	4–3
	37	4	4–5		4	5	5–6 6–5
Lupus	3	4	4–3				
	4	3	4		5	4	4–5
	5	4	4–3	Cor. Australis	5	5	5–6
	10	4	4–5		8	6	5
	11	omitted	omitted		9	5	6
	12	4	4–5		10	5	6
	16	5	5–4		11	6	5–6
	17	6	5–6 6–5		12	5	5–6
				Pisc. Australis	6	6	5–6
	18	6	6–7		9	5	5–4
	19	5	5–6		11	3	3–4

1885, *June* 11.

Observations of the Satellites of Saturn and of the Companion of Sirius, made at the U.S. Naval Observatory, Washington. By Professor Asaph Hall, U.S.N.

(*Communicated by Commander A. D. Brown, U.S.N., Superintendent.*)

Conjunction of the Satellites of Saturn.

Mimas.

Date.	Wash. M.T.	Position.	Weight.	Remarks.
	h m			
1884, Sept. 22	15 57·6	S.	3	
	Enceladus.			
1884, Sept. 22	15 48·6	S.	3	
Oct. 25	13 1·7	S.	2	
1885, Jan. 29	10 22·1	S.	3	
Feb. 16	5 51·7	S.	2	Extremely faint.
18	7 9·8	N.	2	Hazy. Satellite very faint.
20	8 34·1	S.	3	
Mar. 3	7 40·4	S.	3	
14	6 40·7	S.	3	Hazy.
	Tethys.			
1884, Sept. 23	17 29·7	S.	3	
Nov. 16	12 21·1	N.	3	